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REPORT

# Automatic registration feasibility study:

## a simple registration error detector

## No. 1969/50

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

# CORRIGENDA

RESEARCH DEPARTMENT – BRITISH BROADCASTING CORPORATION

Research Report No. 1969/50

*AUTOMATIC REGISTRATION FEASIBILITY STUDY:*
*A SIMPLE REGISTRATION ERROR DETECTOR*

Page 3 – Fig. 4.

Change the ordinate title from 'differentiator output (volts)' to 'relative differentiator output' and label scale 1·0 where curves intersect.

Page 3 – Section 3.2, para. 2, line 3 – After 'shown in Fig. 4' insert additional sentence:

'For the purpose of comparison, the two curves are normalised to produce equal outputs at the frequency of maximum output of the delay line differentiator. (In absolute terms, both curves have slopes, at the origin, of 6 dB/octave.)

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RESEARCH DEPARTMENT

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Head of Research Department

(PH-45)

Research Department Report No. **1969/50**

# AUTOMATIC REGISTRATION FEASIBILITY STUDY: A SIMPLE REGISTRATION ERROR DETECTOR

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# AUTOMATIC REGISTRATION FEASIBILITY STUDY: A SIMPLE REGISTRATION ERROR DETECTOR

## SUMMARY

*In colour television cameras, the light from the scene is divided into three or four suitable components, having different spectral characteristics, which form images on separate camera tubes. The images are correctly registered when the output signals from each camera tube relating to any point in the scene are coincident in time.*

*One possible error in registration is a horizontal offset of one scanned image with respect to another. The device described detects the presence and sense of such an error using signals from a camera viewing normal scenes and the output may be used to control a correction system. With additional apparatus the device can be used to detect errors due to a vertical offset of one image with respect to another.*

## 1. INTRODUCTION

The camera-tube output signals which are derived from the spectral components of the scene may have little or no correlation unless the colours concerned are of low saturation; for most general scenes there are however, a large number of transitions in the separate output signals which are coincident in time when the camera is correctly registered.[1]

The degree of coincidence between the transitions in the two output signals can conveniently be found by subtracting one camera-tube output signal from the other and then measuring the amount of 'detail'[2] in the difference signal (this is equivalent to finding the difference between the separate detail components of the two signals). The result will be a minimum at the point of maximum coincidence of detail, i.e. at the point of best registration.

This principle can be utilized to produce an error detector which responds to the algebraic average of registration errors over, for example, a central area of the picture, the output indicating the presence of a mean displacement of one scanned image relative to another.

One previous proposal suggests that an indication of registration error can be obtained by comparing the relative timings of trains of pulses derived from the detail in normal scenes.[3] A second describes the derivation of correlation coefficients relating to corresponding discontinuities in the luminance signal and the colour signals from a four-tube camera, the correlation coefficients being a maximum when the channels are perfectly registered.[4]

The simple error detector which is the subject of this report does not involve correlation, which is a multiplicative process. The principle used is that subtraction of the detail component of any one signal from that of another will give a result which is a minimum when the detail in the two signals is coincident in time.

## 2. POSSIBLE LIMITATIONS ON PERFORMANCE

### 2.1. Colour detail

Highly coloured detail in the scene can have an appearance similar to that of a misregistered picture and can therefore be wrongly identified as misregistration. If this type of colour detail is the only detail occupying a certain area of picture, and error detection is restricted to this same area, the error signal will consist entirely of spurious information. If, however, the area over which error detection is carried out is made sufficiently large so as to include some normal detail, then the effect of the spurious information will be accordingly reduced.

It is anticipated that colour detail capable of creating spurious information will mainly be concentrated in small areas rather than be distributed evenly over the picture. On this basis it is preferable to carry out error detection over a large area of picture so as to reduce the probability of a high proportion of spurious information at the output.

### 2.2. Residual Misregistration

If the error detector system is based upon average registration errors it may be that errors which occur in one direction on one side of the picture are cancelled by others in the opposite direction on the other side of the picture. If there is some degree of unbalance between the amounts of error occurring in one direction and the other, an automatic 'shift-correction' system* could tend to remove the errors in the one area of the picture but increase the errors in the remaining area.

Changes in the distribution of detail over the picture area will thus result in variations of the compromise conditions of registration, and the maximum change of registration occurring in this way will be equal to the largest residual error. Since residual errors are usually much greater around the edges of the picture, a method of inhibiting the operation of the error detector in this region could provide a useful reduction in unwanted readjustments due to residual misregistration.

---

* A system correcting image-displacement errors by adjustment of electrical shift in the deflection system associated with the camera tube.

### 2.3. Sensitivity

If the operation of the error detector is inhibited around the edges of the picture as a protection against the effects of residual misregistration, then the sensitivity, which is proportional to the area of picture used for error detection, will be reduced. Furthermore spurious indications due to colour detail will become more significant and, in the limit, would mask the remaining sensitivity.

The picture area chosen for error detection will thus be a compromise between, on the one hand, unwanted indications due to residual misregistration and, on the other, loss of sensitivity coupled with the increased significance of spurious signals due to colour detail.

### 2.4. Camera-Tube Lag

If the times for the build-up and decay of signals from one camera tube do not match those from another tube, a rapidly moving scene will appear misregistered. For this reason the time constant of the correction system should be made long enough so that the momentary effects of lag are ignored.

## 3. PRINCIPLES OF OPERATION

As already stated, the first step in detecting misregistration between two images is to subtract the output of one camera tube from that of the other. An electronic measurement of the detail in the difference signal is then made by differentiating it, full-wave rectifying the derivative so that all the waveform excursions are of the same sign, and then integrating the result.

Figure 1 shows a typical response which might be so obtained if the horizontal scan of one tube is shifted through the point of registration with another tube.

### 3.1. Unwanted Responses

The plateau of the response extends until the next coincidence of signal transitions occurs. With signals originating from a grille pattern, for example, response minima will occur at intervals equal to the width of a grille square, as shown in Fig. 2. With signals originating from a normal scene, other subsidiary minima will occur as some transitions of one signal register with non-corresponding transitions of the other signal. These minima might be as shown in Fig. 3.

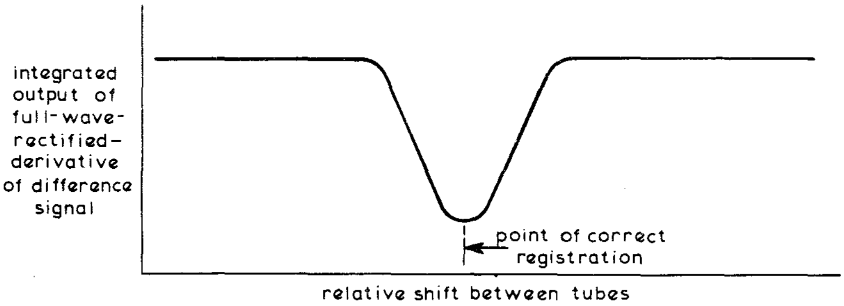

*Fig. 1 - Variation of detail in the difference signal against shift*

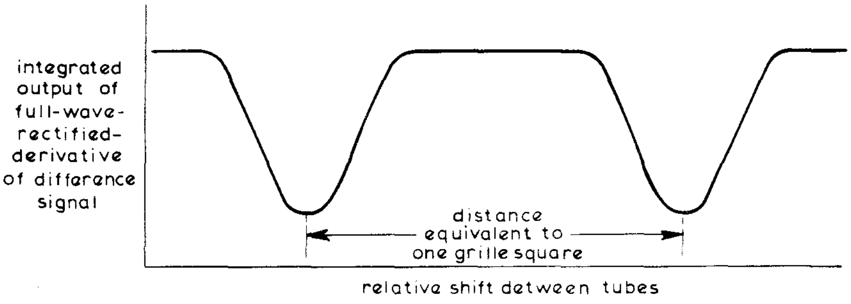

*Fig. 2 - Signals originating from a grille pattern produce minima at spacings equivalent to one grille square*

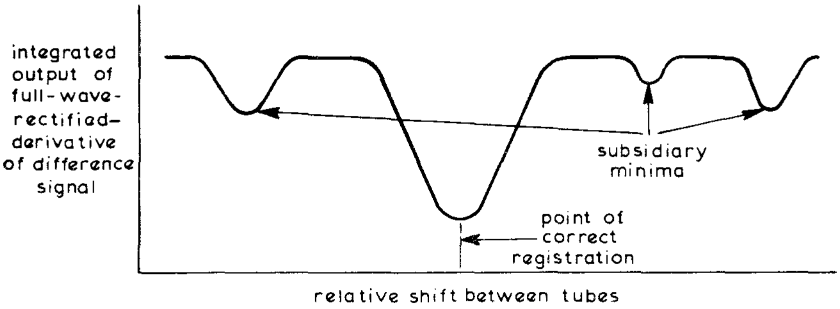

*Fig. 3 - Signals originating from a normal scene produce small subsidiary minima*

The effect of these unwanted minima can, however, be ignored provided their spacing from the main minimum is greater than the range of error detection required.

### 3.2. Obtaining the Derivative

One method of differentiating a signal $S$, where $S$ is a function of time, is by taking $\Delta S/\Delta t$ rather than $\mathrm{d}S/\mathrm{d}t$, where $t$ represents time. This may be realised as $(S - S_{\Delta t})$, where $S_{\Delta t}$ is the signal $S$ delayed by an increment of time $\Delta t$.

A comparison between the frequency characteristic of this form of differentiator and that of a true derivative is shown in Fig. 4. It can be seen that, providing the frequency of maximum output $f_m$ $(= 1/2\Delta t)$ is greater than the maximum frequency of the signal to be differentiated, the characteristics are broadly similar. In practice the input signals are passed through a low-pass filter having a sine-squared response and a cut-off frequency below $f_m$. This ensures the above condition whilst at the same time providing a useful protection against noise.

### 3.3. Direction of Error

If the two signal inputs are respectively $A$ and $B$, then the difference signal which produces the original response, as shown in Fig. 1, is $(A - B)$.

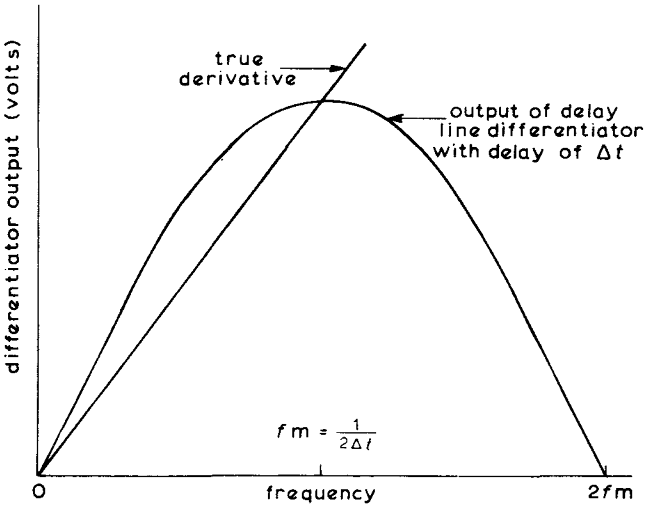

*Fig. 4 - Relationship between the response of a delay line differentiator and the true derivative*

Since the response shown in Fig. 1 can give no indication of the direction of the registration error, it is necessary to produce an error signal of such a form that it indicates on which side of the point of correct registration the image lies. This is achieved by creating two separate responses and then amplifying the difference between them to produce an output. One response is derived after delaying signal $B$ by a suitable period and then subtracting it from signal $A$, while the other is derived after delaying signal $A$ and subtracting the undelayed signal $B$. The responses due to these two difference signals $(A - B_T)$ and $(A_T - B)$ are shown in Fig. 5(*a*).

A direction-sensitive error signal is then produced by subtracting one of these responses from the other, the resulting output characteristic being as shown in Fig. 5(*b*). It can be seen that the output is zero at the point of correct registration.

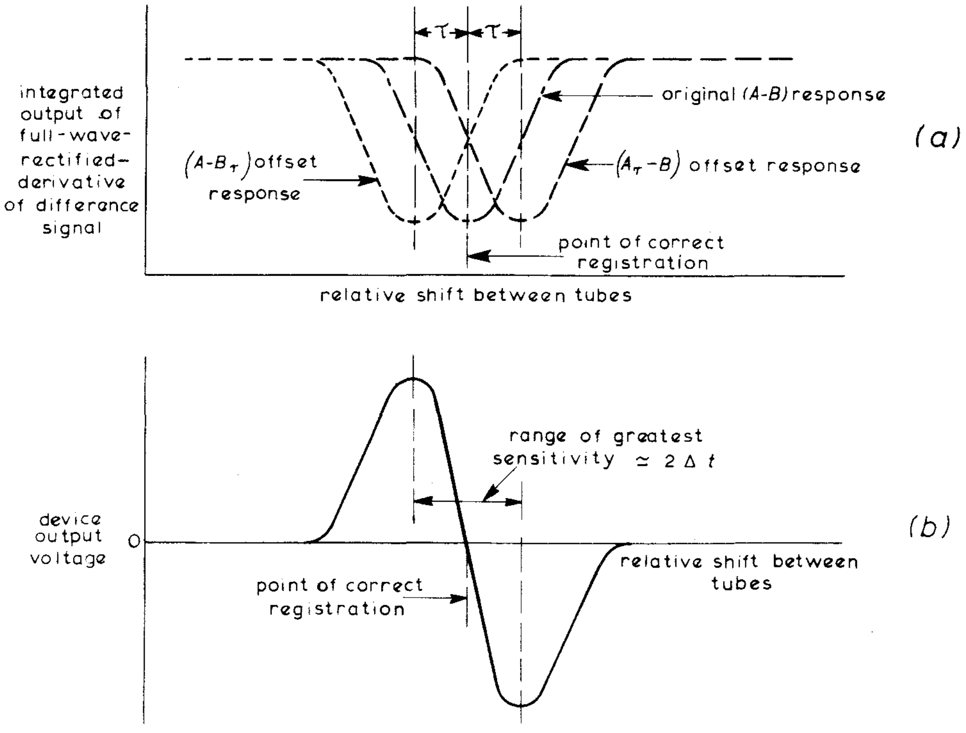

*Fig. 5 - Creation of offset responses to obtain a direction sensitive output*

(*a*) Two similar responses offset to either side of the original response by delaying signals $A$ and $B$ respectively

(*b*) Output characteristic resulting from the subtraction of the two offset responses shown in (*a*)

As shown in Fig. 5(*a*), the two offset responses are:

$$(A - B_\tau) \quad \text{and} \quad (A_\tau - B)$$

where $A_\tau$ is signal $A$ delayed by time $\tau$.

$B_\tau$ is signal $B$ delayed by time $\tau$.

The derivatives of these, using the method discussed, are:

$$(A - B_\tau) - (A - B_\tau)_{\Delta t} \tag{1}$$

$$(A_\tau - B) - (A_\tau - B)_{\Delta t} \tag{2}$$

The above may be re-written

$$A - B_\tau - A_{\Delta t} + B_{(\tau + \Delta t)} \tag{3}$$

$$A_\tau - B - A_{(\tau + \Delta t)} + B_{\Delta t} \tag{4}$$

### 3.4. Maximum Sensitivity

For maximum sensitivity around the point of registration the two offset responses should intersect where their slopes are greatest (Fig. 5(*a*)). This approximately* corresponds to their half-amplitude points. Since the half-amplitude width of each response is approximately equivalent to a shift given by a time delay of $2\Delta t$ and the spacing of the minima is $2\tau$, the value of $\tau$ may be made equal to $\Delta t$. The resulting linear range of the output characteristic in Fig. 5(*b*) will now be approximately $2\Delta t$ and the overall useful range will be a little more than twice this.

The deratives given by Equations (3) and (4) now become:

$$A - B_{\Delta t} - A_{\Delta t} + B_{2\Delta t} \tag{5}$$

$$A_{\Delta t} - B - A_{2\Delta t} + B_{\Delta t} \tag{6}$$

$A_{\Delta t}$ and $B_{\Delta t}$ are signals $A$ and $B$ delayed by time $\Delta t$.

$A_{2\Delta t}$ and $B_{2\Delta t}$ are signals $A$ and $B$ delayed by time $2\Delta t$.

## 4. A PRACTICAL CIRCUIT ARRANGEMENT

The successful derivation of an error-signal having the form of that shown in Fig. 5(*b*) would clearly permit servo-control of the parameter affecting the registration of the picture, provided the error is not greater than $\pm 2\Delta t$.

Equations (5) and (6) may each be realized using one subtraction and two additions and this choice allows considerable saving in circuit complexity since each addition may be made using a simple passive network.

Signals $A_{\Delta t}$, $A_{2\Delta t}$, $B_{\Delta t}$ and $B_{2\Delta t}$ are obtained from delay lines as shown in Fig. 6(*a*). The required sums are obtained using equal resistors $R$ (Fig. 6(*b*)) and these are fed to long-tailed pair differential amplifiers which act as subtractors. The outputs of these amplifiers are full wave rectified and integrated to produce the two offset responses shown in Fig. 5(*a*). A further differential amplifier responds to the difference between these integrals to produce the output signal.

Further details of the circuit used are given in Appendix I.

## 5. OBSERVED PERFORMANCE

### 5.1. Sensitivity

The error detector as described in Appendix I has a sensitivity of about 400 mV per nanosecond of horizontal registration error, using signals originating from a grille pattern, over the total picture area. The sensitivity is dependent upon the number and amplitude of edges in the picture and for normal pictures is reduced to about one fifth of that obtained using a grille pattern; the sensitivity is further reduced when error detection is limited to a central picture area.

### 5.2. Zero Drift

Output drift was observed to be mainly due to the integrated-circuit differential amplifier used to subtract one error response from the other. It is of thermal origin and amounts to ±500 mV for the range of ambient temperatures encountered in the laboratory; however, a considerable reduction of this drift should be possible by suitable design.

### 5.3. Unwanted and Spurious Indications

#### 5.3.1. Residual Misregistration

This was found to be the major cause of unwanted indications. It was found necessary to detect errors in only the centre portion of the picture, where residual misregistration is much less prevalent, in order to keep the unwanted indications within acceptable limits.

#### 5.3.2. Colour Detail

To measure the effect of spurious indications due to colour detail, inherently registered pictures were used (from a flying-spot film scanner). With error measurement over a central portion of the picture equal to half the total area (70% height and 70% width) it was found that colour detail could cause errors equivalent to relative timing errors between the channels of up to 5 ns.

#### 5.3.3. Circuit Unbalance

Spurious readings can be caused by a difference in the a.c. gain of the two long-tailed pair amplifiers. This will allow noise or other uncorrelated detail, or any difference in amplitude of the input signals to produce an output error indication. The effect cannot be identified separately from that of colour detail and thus the spurious readings discussed under colour detail must also include any effects of circuit unbalance.

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* The exact shape of the responses is dependent upon the nature of the transitions in the input signals which are in turn subject to the effect of the low-pass input filters.

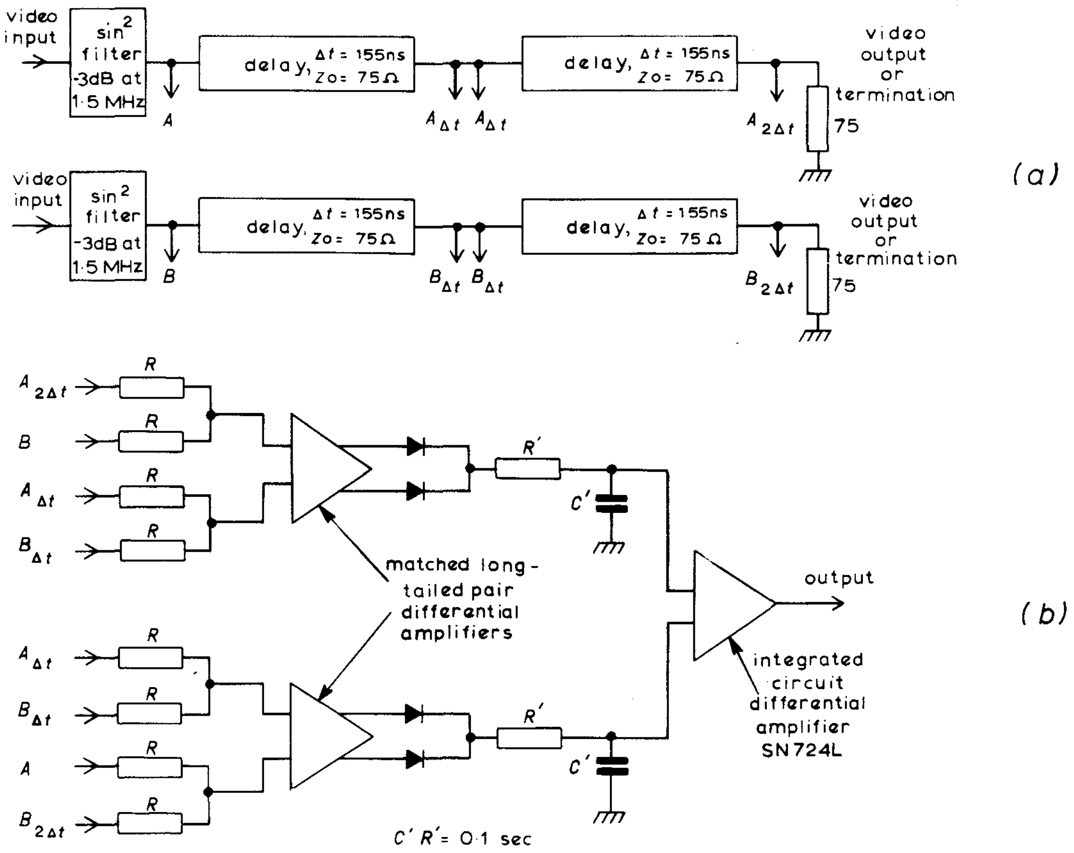
video input
$\sin^2$ filter -3dB at 1·5 MHz
delay, $\Delta t$ = 155ns, Zo = 75Ω
A
$A_{\Delta t}$ $A_{\Delta t}$
$A_{2\Delta t}$
video output or termination
75
(a)
video input
$\sin^2$ filter -3dB at 1·5 MHz
delay, $\Delta t$ = 155ns, Zo = 75Ω
B
$B_{\Delta t}$ $B_{\Delta t}$
$B_{2\Delta t}$
video output or termination
75
$A_{2\Delta t}$
B
$A_{\Delta t}$
$B_{\Delta t}$
R
R'
C'
matched long-tailed pair differential amplifiers
output
(b)
integrated circuit differential amplifier SN724L
$A_{\Delta t}$
$B_{\Delta t}$
A
$B_{2\Delta t}$
C' R' = 0·1 sec

*Fig. 6 - Circuit arrangement*
(*a*) Derivation of required signals using delay lines
(*b*) Block schematic showing how the output is produced from the signals derived in (*a*)

### 5.3.4. Camera-Tube Lag

No effects due to lag have been observed and it may be assumed that an output time constant of 0·1 seconds, as used in the prototype detector, is sufficiently long to mask the effects of lag on rapidly moving pictures.

## 6. VERTICAL ERROR DETECTION

The principles described can be adapted for vertical error detection. In this case, each unit of delay ($\Delta t$) must be an exact multiple of one line period.

## 7. CONCLUSIONS

The device described has been found capable of indicating misregistration between two tubes of a colour camera, and although circuit improvements could be made in respect of drift and unbalance, errors due to these shortcomings have been found insignificant under normal operating conditions.

Spurious indications due to colour detail being wrongly identified as misregistration are also small, provided that error detection is carried out over at least half the total picture area.

The largest errors are due to residual registration errors in the camera which may or may not average to zero depending upon the position of detail in the scene. If the error detector were used to control an automatic centering system a change in shift due to the largest residual error could result. It should be noted that the usefulness of servo-control of picture centering as a means of automatic registration of colour television cameras is dependent upon the stability of scan amplitudes and linearities. There is evidence[5] to show that these are satisfactorily constant but it is also important that the intrinsic registration of the camera should be good. The effect of residual errors can be reduced to acceptable limits by limiting the area of operation of the error detector to the centre portion of the picture.

## 8. REFERENCES

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3. MONTEATH, G.D. *and* ROUT, E.R. Registration of television camera tubes. British Patent Application No. 38502/68.

4. RAINGER, P. Television camera registration. British Patent Application No. 10911/69.

5. Automatic registration feasibility study: the scanning stability of an EMI type 2001 colour camera. BBC Research Department Report in preparation.

## *APPENDIX I*

### *Practical Circuit Arrangement*

### 1. GENERAL

The input video signals are obtained from the camera channel prior to any contour correction, matrixing, or gamma-correction operations. These signals are passed through sine-squared low pass filters, which have 3 dB loss at 1·5 MHz and infinite attenuation at approximately 3·0 MHz, to produce signals $A$ and $B$.

Signals $A_{\Delta t}$, $A_{2\Delta t}$, $B_{\Delta t}$ and $B_{2\Delta t}$ are then obtained as previously discussed by delaying signals $A$ and $B$ as shown in Fig. 6(*a*). The unit of delay $\Delta t$ was made 155 ns and thus the frequency of peak response $f_m$ (Fig. 4) is given by

$$f_m = \frac{1}{2\Delta t} = \frac{1}{310 \times 10^{-9}} = 3{\cdot}23 \text{ MHz}$$

A block schematic of the remainder of the circuit appears in Fig. 6(*b*). The sums $(A + B_{2\Delta t})$, $(A_{\Delta t} + B_{\Delta t})$, and $(A_{2\Delta t} + B)$ are obtained using equal resistors whose values are large compared with the characteristic impedance of the delay lines so as to avoid matching problems and unwanted crosstalk.

The two subtractions are performed by long-tailed pair differential amplifiers and full wave rectification is accomplished using the antiphase collector voltages of these amplifiers. The output of each full wave rectifier is integrated by a resistor and capacitor with a time constant of 0·1 seconds and the two integrals are then fed to a high gain differential amplifier which produces the final output.

### 2. STABILITY

Since the difference between the two integrals is only a few millivolts, the d.c. conditions of the two long-tailed pair amplifiers and full-wave rectifiers must be accurately matched. Further, the a.c. gains must be accurately matched over a bandwidth of approximately 3·0 MHz to prevent spurious error output signals being caused by noise, other uncorrelated detail, or a difference in the amplitudes of the input signals (the performance above 3·0 MHz is not critical since the input signals are band limited). Dual transistors are used throughout to obtain the required performance over a 50°C temperature range. The basic circuit is shown in Fig. 7.

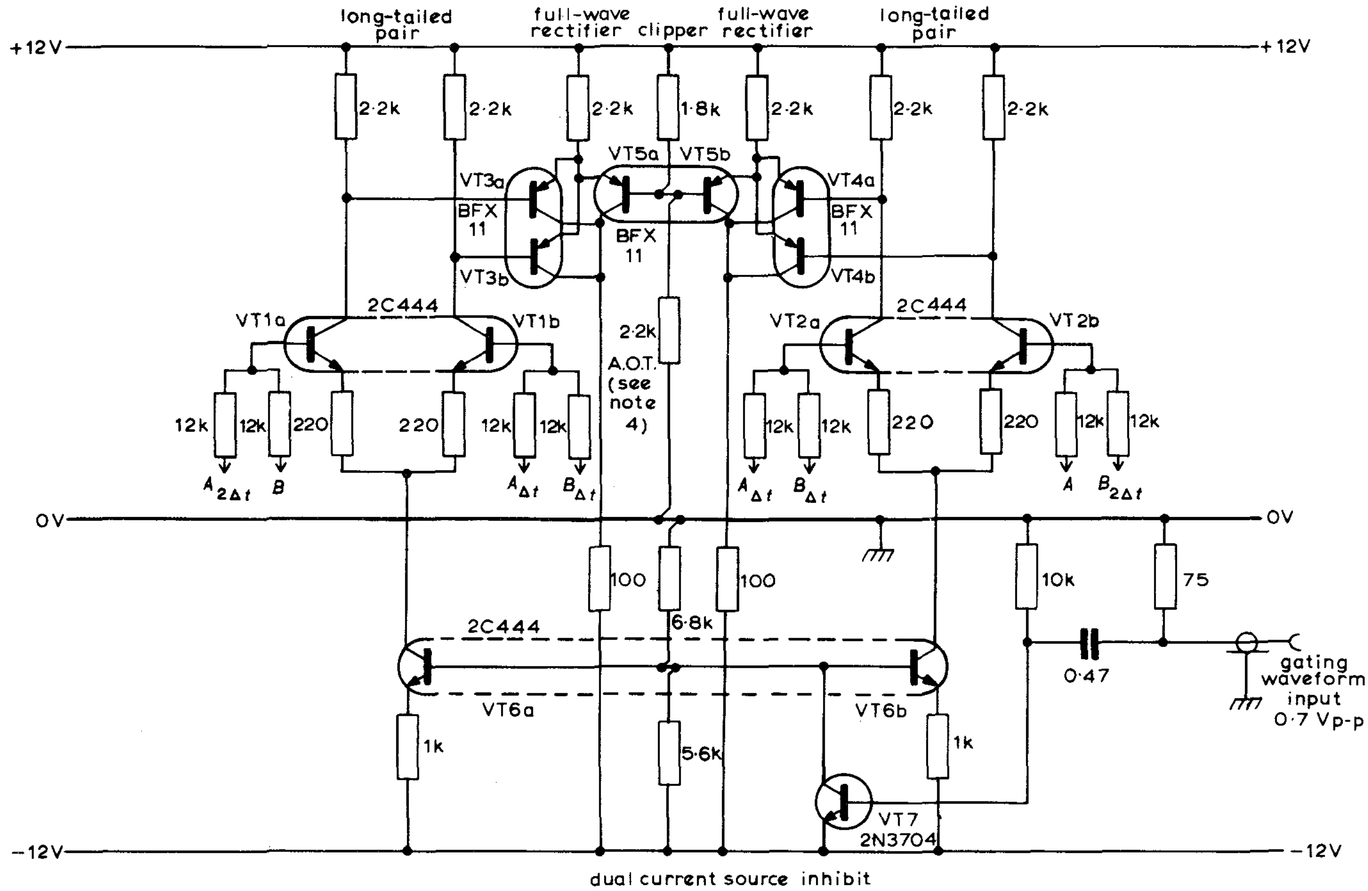

*Fig. 7 - Basic circuit of matched long-tailed pair differential amplifiers and full wave rectifiers*

Notes: adjustment of d.c. condition

1. Adjust one emitter resistor of each long tailed pair to make the collector voltages equal
2. Adjust one emitter resistor of dual current source to make collector voltages of VT1 and VT2 equal ±10 mV
3. Adjust so that VT5a/VT5b base potential is 0·1V below long tailed pair collector potentials

The clipper transistor pair VT 5a, VT 5b requires special mention, since it is this which determines the output potentials to the integrators when there is no signal output. The difference between these potentials must not drift by more than 500 $\mu$v for 50°C temperature change. However the collector potentials of the long-tailed pairs can drift up to 7·5 mV, and if this drift appeared at the output it would mask all other indications. For this reason the d.c. conditions are adjusted so that the clipper transistors determine the output potential. These have a common base potential and the maximum base-emitter differential voltage change is less than 500 $\mu$v over the 50°C temperature range. The full wave rectifier transistors take over from the clippers when the signals at the long-tailed pair collectors exceed 100 mV.

Finally since the small difference between the two integrals may be accompanied by a large common-mode signal, high common-mode rejection is required in the output differential amplifier together with good thermal stability. The integrals are low-bandwidth signals, so an integrated circuit differential amplifier with an upper-frequency limit of about 10 Hz is used; an amplifier gain of about 1000 gives a peak output voltage of ±5 volts for 10 ns of misregistration in either direction, with input signals corresponding to a grille pattern covering the whole picture area.

## 3. GATING OF PICTURE AREA

The operation of the device may be inhibited by turning on the inhibit transistor VT 7. This suppresses the dual current source, and all four long-tailed pair collectors then go positive, the output potentials to the integrators being held by the clipper transistor pair VT 5a, VT 5b.

Thus VT 7 may be driven by a gating waveform to allow operation only over a particular area of picture.

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